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GRAIN SIZE STABILITY OF A WINTER BARLEY GENOTYPES ASSORTMENT UNDER DIFFERENT SEED RATES

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Abstract

The grain uniformity of the malting barley has a decisive role in determining the malting quality and the process efficiency. One of the main technological factors which influence malting barley quality, including the grain size and the grain uniformity is the seed rate. Starting from these ideas, the objective of this study was to evaluate the response of different winter barley genotypes to different seed rates and to identify winter barley genotypes with high stability regarding seed size fractions as related with grain yield across two seed rates. In this respect, eighteen winter barley genotypes were tested for grain yield and size seed fractions for three consecutively years (2017, 2018, 2019) at National Agricultural Research and Development Institute Fundulea (NARDI Fundulea). In order to be used in brewing industry, the value of barley seeds is estimated based on their size, namely assortment (size of seed >2.8 mm and >2.5 mm/assortment I+II). The contribution from the average yield of each genotype, representing the percentage of seeds larger than 2.5 mm and 2.8 mm, was evaluated and the response of studied genotypes to the different seed rates were determined on the ANOVA and coefficient of variation basis. ANOVA showed that year (Y), genotype (G), year x genotype (Y x G), seed rate x genotype (S x G) and triple interaction year x seed rate x genotype (Y x S x G) significantly influenced the seed size >2.8 mm and 2.5 mm with a coefficient of variation of 6.47% and 31.7%, respectively. As source of variation, the seed rates (S) and interaction between year x seed rate (Y x S) was insignificant for both category seed size. The most winter barley genotypes had a positively response to the lower seed rate, both for yield and seed assortment, especially for seed size >2.8 mm.

***Key words**: winter barley genotype, assortment, seed rate, grain size, yield.*

INTRODUCTION

Barley (*Hordeum vulgare* L.) has three main uses: feed, food, and malt production (Newton et al., 2011).

With more than 51 million ha harvested area in 2019 and with a production of about 159 million tons (FAOSTAT, 2019), barley is the fourth cereal crop worldwide.

A significant challenge for delivering grain with consistent yield and quality in the future is climate change due to the complex effects of atmospheric CO_2 and changing temperature and rainfall patterns on barley development (Nuttall et al., 2017). Multiple traits such as yield and quality of grains are routinely evaluated in barley breeding programs (Bhatta et al., 2020), but grain yield and its components are highly influenced by environmental factors and agronomic management practices (Khumalo, 2020).

In Romania, there is a reference document for malting barley (SR ISO 13477) and in the Grading Manual of Grains for Consumption (2017), three grades are mentioned based on minimum percent seeds larger than 2.5 mm, respectively: Grade I, Grade II, and Grade III, with minimum 85%, 75%, and respectively 70% seeds larger than 2.5 mm. The malt and beer industry use as raw material the seeds >2.5 mm (Petcu et al., 2019). For brewery industry, there will be used only barley grains which reach the standardized rules such as disease-free seeds, low protein content, plumpness of grains and none of the less seed uniformity (Brewing and Malting Barley Research Institute, 2010).

Grain size is an important quality parameter of malting barley, this being dependend on genotypes, environmental factors and their interactions (Stupar et al., 2017). However, this grain quality parameter has to be associated with the grain content of starch and protein, the starch content having to be as high as possible, while the protein content having to be less than 11.5%, but no less than 9%. Also, it has to be considered that during the brewing process, starch is converting in malt extract and this is facilitated by uniform and plump grains and this conducts to an increase extract levels (Mather et al., 1997).

The size and uniformity of the grains have a decisive role in determining the level of malting process efficiency. Thick grains have a high content of extractable substances and a higher germination energy. A reduced uniformity of the grains translates into appreciable losses of raw material and low yields. The I+II grain assortment (percent of grains larger than 2.8 mm and 2.5 mm, respectively) constitutes an important index both for uniformity and size of the grains (Drăghici et al., 1975).

One of the main technological factors which influence malting barley quality, including the grain size is the seed rate, respectively the seed density. Wade & Froment (2003) had been found that seed rate influenced malting barley quality, respectively the grain size uniformity.

A study on relationship between malt quality and seed rates conducted by McKenzie et al. (2005) in southern Alberta revealed that increased seed rates from 150 to 350 viable seeds m^{-2} generally provided small yield gains, slight reductions in grain protein concentration and reduced grain size. As the sowing rate increases, it is expected that the grain size decreases.

O'Donovan et al. (2011) performed a field experiment during 4 years and stated that for CDC Copeland and AC Metcalfe barley varieties grain weight and plumpness were lower at the higher seeding rate (400 seeds/m^2) but seeding rate had no effect on grain yield. Another multi-location research was made to study the effect of seed date and seed rate on malting barley production in western Canada which showed that a 300 seed/m^2 maintained the yield and increased the grain size which improve the potential for higher economic returns for barley growers (O'Donovan et al., 2012; O'Donovan et al., 2009). Spaner et al. (2001) obtained similar results when barley density increased, the seed size (plumpness) being lower and grain size being significantly affected by seed rate. Paynter et al. (2013) indicated a specific seed rate which maximized the yield per ha and how influenced the phenotypic traits and grain quality (grain and hectoliter weight, protein content and seed size).

Grain yield represents the interaction between yield components and, at their turn, these interact with each other. The result can be an increase of one of them leading to a decrease of other, but it is possible to breed a character independently by other (Zhou et al., 2016). The yield capacity is an important trait that barley varieties must possess and express to a higher level to finally appreciate the agronomic value of the genotypes. A valuable barley genotype must have the capacity to grow in normal conditions of cultivation, having in the same time a higher adaptability when the climatic conditions are unfavorable with large variations of temperature and rainfall of a given region (Drăghici et al., 1975). One of the most important factors in maximizing crop yield is the high quality seed (Zareian et al., 2013). The optimal number of seed used for sowing has a significant impact in the final yield. Using a lower seed rate can cause an irregular and unbalanced uniformity and ripening of the grains due to extension of tillering and forming the first spikes in different periods of time. A higher plant density can determine lodging of the plants specially to genotypes who do not have lodging resistance (Drăghici et al., 1975).

In this respect, the objective of this study was to evaluate the response of different winter barley genotypes to different seed rates and to identify winter barley genotypes with high stability regarding seed size fractions as related with grain yield across two seed rates. It was intended to find out which is the seed rate that can maintain barley grain size to acceptable required levels for registered varieties, but also for promising breeding lines, and to compare the stability of their yield and the grain size.

MATERIALS AND METHODS

Eighteen winter barley genotypes (six-rows varieties and lines) developed at National Agricultural Research and Development Institute Fundulea (NARDI Fundulea) were sown in field conditions for 3 consecutively years, respectively 2017, 2018, and 2019 under two different seed rates: lower seed rate using 350 seeds/m^2 (TS1 = technological sequence 1) and classical seed rate for barley in the specific growing conditions of Romania, with 500 seeds/m^2 (TS2 = technological sequence 2).

The researches were performed within Barley Breeding Experimental Field (BBEF) belonging to NARDI Fundulea, which is situated in South Romania, Fundulea town (44°33' Northern latitude and 24°10' Eastern longitude). The analysed genotypes were created at NARDI Fundulea and included eight winter barley varieties (Dana, Cardinal FD, Univers, Ametist, Smarald, Simbol, Onix, Lucian) and ten advanced lines (F8-2-12, F8-3-01, F8-3-12, F8-4-12, F8-5-12, F8-6-12, F8-10-12, F8-11-12, F8-5-13, F8-6-17).

Each seed rate was established every year for each variety and line based on their grain weight and the plot area. The harvested plots had 4.5 m^2 harvested area in three replications. After harvest, the grain yield (GY) was determined by weighing each replication and it was expressed in kg/ha at 14% moisture content.

To assess seeds size, one hundred grams of grains in three replicates were analysed with Sortimat machine which is designed for sieving based on plumpness of grains. After sieving within 3 different dimensions (seeds size >2.8 mm, seeds size >2.5 mm, seeds size >2.2 mm), the seeds were weighted using the electronic balance with 2 decimals and each seed category was reported as percent.

The obtained data were analysed with MSTAT C program. In order to evaluate and compare winter barley yield and seed size stability of the varieties and lines grown under different seed rates and climatic conditions, for each studied parameter (grain yield and the two seed size dimensions >2.8 and >2.5 mm) the standard deviation was calculated. A low standard deviation indicates that the values tend to be close to the mean of the studied barley genotypes sets, while a high standard deviation indicates that the values are spread out over a wider range.

The meteorological data were provided by a weather station located nearby experimental fields of NARDI Fundulea. The evolution of climatic data during barley growing period in the spring (period March - June) indicates different distribution of rainfall each month comparing with long term average (60 years). The lowest level of rainfall has registered in April and May, 2018 year, with a difference of 42.2 mm (March) and 27.5 mm (May) comparing with multiannual average (Figure 1). The exceeding of rainfall occurs in May, 2019 year, being registered almost double quantity of rainfall compared to the average of multiannual rainfall.

Temperatures tended to gradually grow each year in March from 3.3 to 9.3°C, comparing to multiannual average being higher with 4.6°C in 2019 and with 2.4°C in 2017 (Figure 2). In June, all average temperatures tended to grow, from 22.2 to 23.6ºC, in all the years the temperatures being higher than the multiannual average. In April and May, in 2018 there were registered the highest temperatures, while the temperatures in these months in the years 2017 and 2019 being closed to the multiannual average.

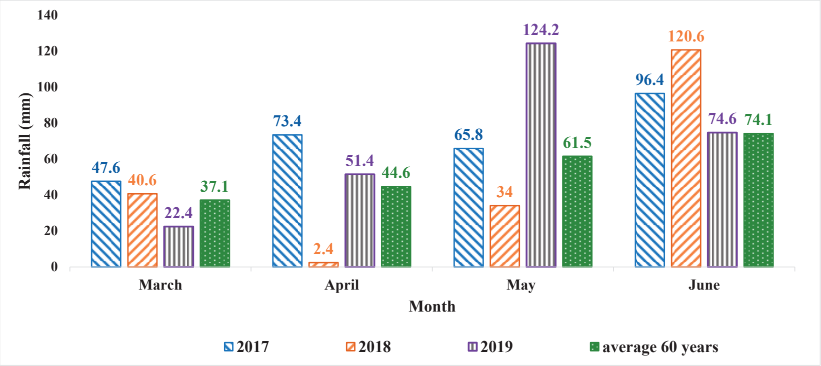

Figure 1. Average rainfall during barley growing period in the spring and multiannual average (1957-2017)

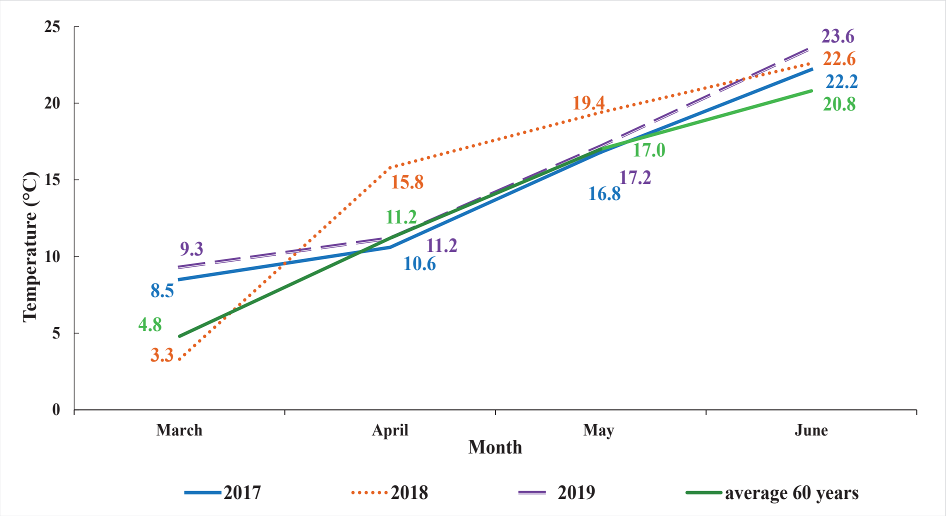

Figure 2. Average temperature during barley growing period in the spring and multiannual average (1957-2017)

RESULTS AND DISCUSSIONS

Analyze of variance showed that grain yield was influenced by seed rate, genotypes and their interaction with the climatic conditions of the year (Y x S and Y x G) (Table 1). The triple interaction Y x S x G was unsignificant for grain yield. As source of variation, year, genotypes, and the interactions Y x G, S x G and Y x S x G have significantly influenced on all three seed size, while seed rate and interaction between Y x S had an unsignificant influence of them.

The coefficient of variation registered the smallest values for the seed size >2.8 mm and for the grain yield, while the seed size categories >2.5 but especially >2.2 mm registered the highest values (Table 1).

Table 1. Analyse of variance for yield and seed size

No.	Source	Degree of freedom	F factor			
			Grain yield	Seed size >2.8 mm	Seed size >2.5 mm	Seed size >2.2 mm
1.	Year (Y)	2	1.8571 n.s	99.8767 **	85.9850 **	273.0696 **
2.	Seed rate (S)	1	15.9087 **	0.4268 n.s	0.8077 n.s	0.3806 n.s
3.	Y x S	2	9.0871 **	0.0829 n.s	1.6240 n.s	0.3752 n.s
4.	Error	10	-	-	-	-
5.	Genotypes (G)	17	5.2125 **	7.8963 **	16.8496 **	16.5117 **
6.	Y x G	34	5.0453 **	3.8809 **	7.4529 **	10.3322 **
7.	S x G	17	1.1044 n.s	2.2680 *	4.6245 **	2.1184 *
8.	Y x S x G	34	0.8270 n.s	2.4043 **	4.5593 **	1.6107 *
9.	Error	204	-	-	-	-
		CV%	10.47	6.47	31.77	45.52

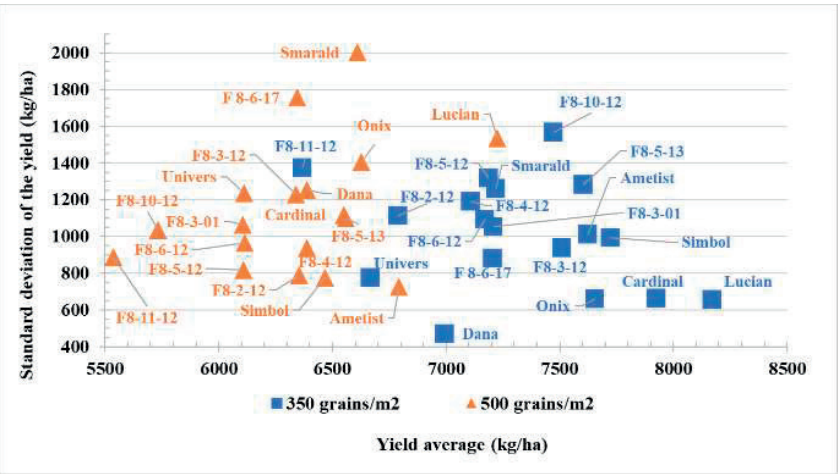

Figure 3. Yield results for TS1 and TS2 as average for 3 years

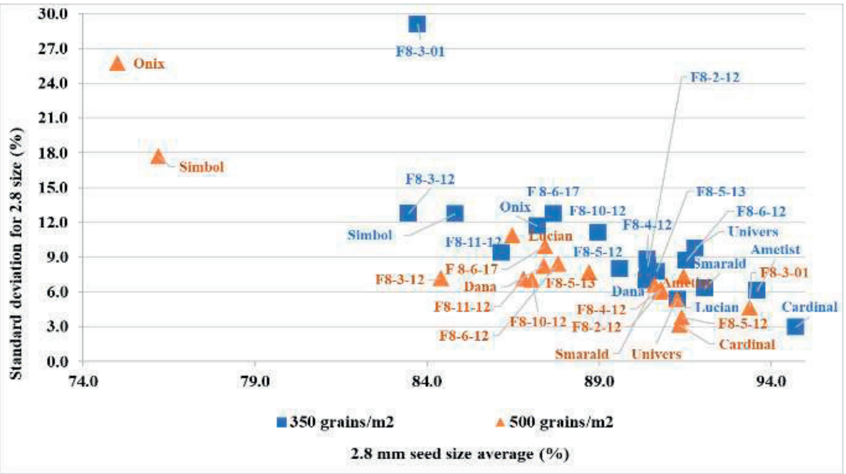

Figure 4. Grain size average (2.8 mm) and standard deviation (%)

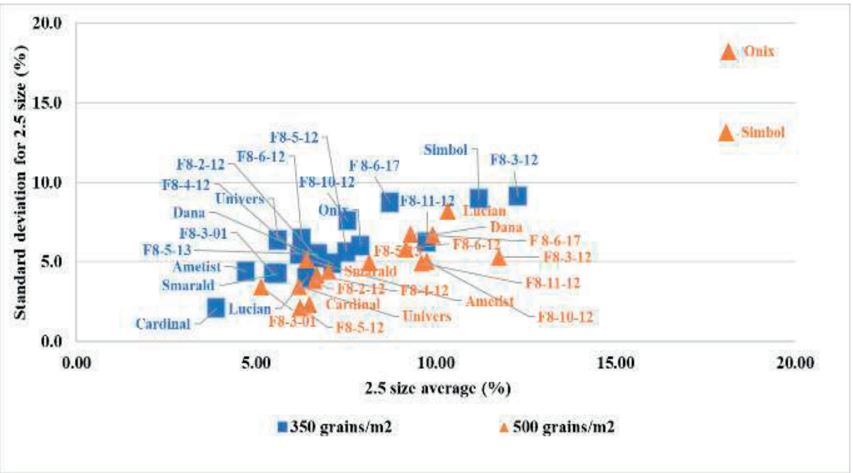

Figure 5. Grain size average (2.5 mm) and standard deviation (%)

In Figure 3, the tested winter barley genotypes are graphic represented by two different colours: blue colour for TS1 - 350 grains/m^2 and brown colour for TS2 - 500 grains/m^2. Average yield level (average of 3 years) was plotted against standard deviation of each barley genotype. Almost all genotypes had a good response regarding their yield potential under TS1 (350 grains/m^2) compared with the TS2 (500 grains/m^2) except the line F8-11-12 which registered the lowest yield and also was very instable, having a higher standard deviation value (almost 1400 kg/ha). The winter barley varieties Onix, Lucian and Cardinal with high yields had the best stability during the tested period under TS1 comparing with TS2, where only Lucian variety has registered a high yield but a smaller stability, and the varieties Simbol and Ametist has registered better stability (with lower yield standard deviation) but lower yields. The check variety, Dana, had the most stable yield, with lowest standard deviation (470 kg/ha) under TS1. The most instable genotypes under TS1 condition were the line F8-10-12 and Smarald variety for TS2 condition.

The analyze for obtained values for 2.8 mm seed size showed that genotypes responded differently to the seed rate (Figure 4). For seed size of 2.8 mm, values ranged between 75% (Onix variety - TS2) and 94.7% (Cardinal variety - TS1). The most stable genotype regarding this parameter was Cardinal with a standard deviation percent below 5% both for TS1 and TS2, the percent of plumpness grains being over 90% for both conditions. Regarding stability of seed size percent of seeds >2.8 mm can be remarked also other genotypes as Smarald, Univers, F8-5-12 under TS2 and Smarald, Ametist and Lucian under TS1 with values over 90%. The highest values of standard deviation have registered under TS2 in the case of Simbol and Onix varieties (17.7 and 25.7% respectively).

The analyze for obtained values for 2.5 mm seed size showed a different tendency of genotypes to the applied seed rate (Figure 5). In general, the grain size of 2.5 mm registered a standard deviation below 10% (TS1) while the same seed size has registered a standard deviation of 18.2% (TS2) and the values ranged between 3.9% (Cardinal - TS1) and 18.14% (Onix - TS2). The most stable genotypes regarding this parameter were also Lucian, Smarald and Ametist with a percent below 5% for TS1 and TS2 (except Lucian variety with 10.32% under TS2). Regarding stability of seed size percent of seeds >2.5 mm, it can be remarked Simbol and Onix varieties with a percent of seed size values over 18.07, respectively 18.14%. The highest values of standard deviation have registered under TS2 in the case of those varieties being 13.2 and 18.2%.

CONCLUSIONS

The response of winter barley genotypes was different for each analised parameter depending on used seed rate (classical density and lower density) and therefore it could be a key to successful and increased yield. The most winter barley genotypes had a positively response to the lower seed rate, both for grain yield and seed assortment, especially for seed size >2.8 mm. Choosing the right genotype adapted to the proper seed rate is one of technological sequence which can provide a high grain yield that meets required raw industry standards.

During the tested period, the most stable winter barley genotypes regarding grain yield level under TS1 (lower density) were Cardinal, Ametist, Simbol, Onix and Lucian varieties.

Developing regionally best management practices regarding seed rate will increase farmer's knowledge base and can be seen as a management tool for maximizing net return for farmers.

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